



GEOS S2S-2_1: GMAO's New High Resolution Seasonal Prediction System

Andrea Molod

GMAO Seasonal Prediction Development/Validation Effort:

Santha Akella, Lauren Andrews, Donifan Barahona, Anna Borovikov, Yehui Chang, Richard Cullather, Eric Hackert, Robin Kovach, Randal Koster, Zhao Li, Jelena Marshak, Siegfried Schubert, Max Suarez, Atanas Trayanov, Guillaume Vernieres, Yury Vikhliaev, Bin Zhao

AGU Fall Meeting, December 2017

New Seasonal Prediction System - GEOS S2S-2_1

Model

- AGCM: Post MERRA-2 (current GMAO NWP) generation 0.5 degree, 72 hybrid sigma/pressure levels; GOCART interactive aerosol model, cloud indirect effect (2-moment cloud microphysics); MERRA-2 generation cryosphere;
- OGCM: MOM5, 0.5 degree, 40 levels;
- Sea Ice: CICE-4.0.

Weakly Coupled Ocean Data Assimilation System

- atmosphere is “replayed” to GMAO near-real-time assimilation fields (system like MERRA-2);
- NCEP-like LETKF code/system, set here to behave as Ensemble OI;
- forecasts: initialized from ODAS, perturbations produced from analysis temporal differences;
- hindcasts: re-initialized from 5-day run of ODAS, perturbations from analysis differences;

Observations

- nudging of SST and sea ice fraction from MERRA-2 boundary conditions;
- assimilation of satellite along-track ADT (Jason, Saral, ERS, GEOSAT, HY-2A, CryoSat-2);
- assimilation of *in situ* Tz and Sz including Argo, XBT, CTD, tropical moorings;
- Sea Surface Salinity data not used.

GMAO's Near Real-Time Sub/Seasonal Prediction Suite

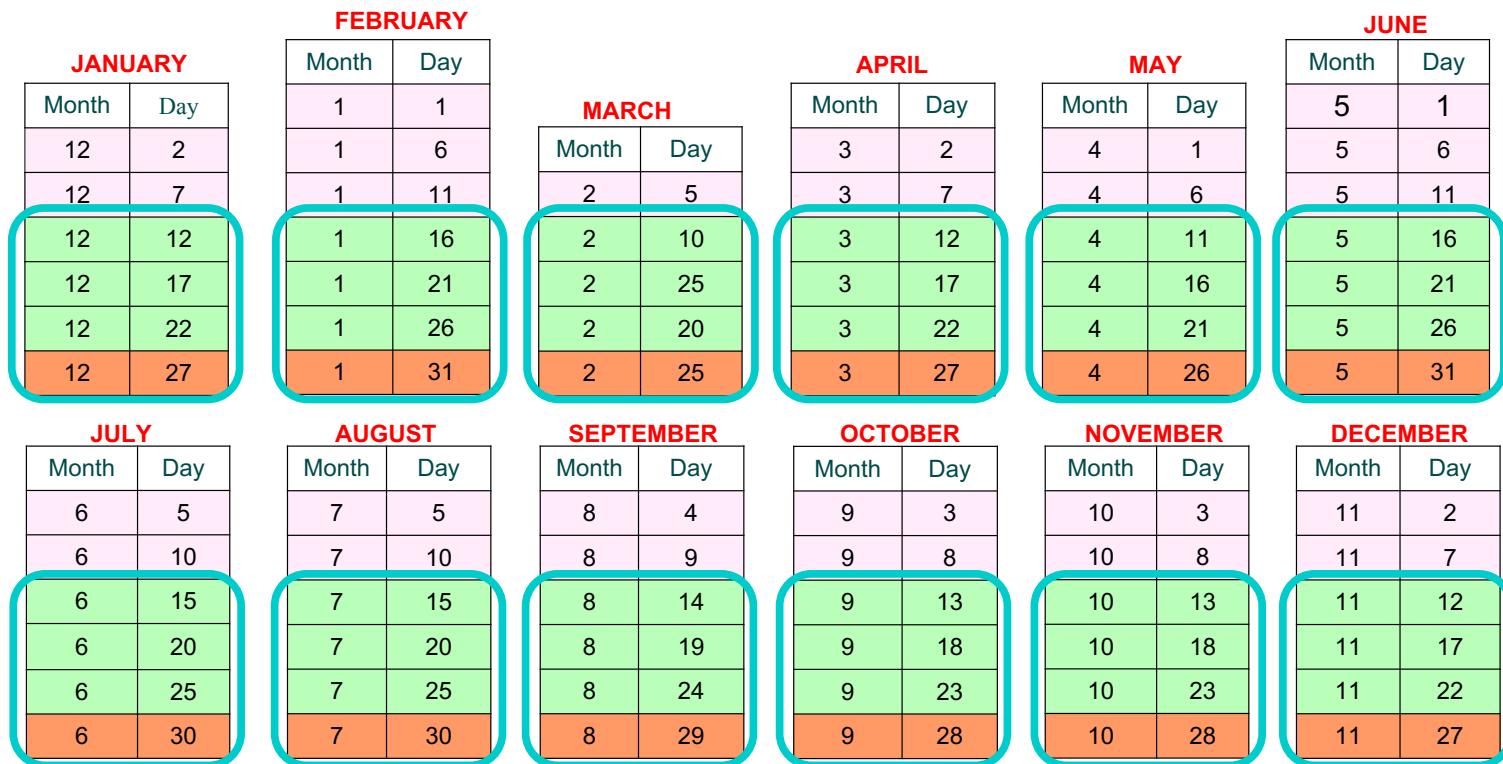
GMAO's GEOS S2S sub/seasonal **forecasts** are part of the National MultiModel Ensemble (NMME). We will also participate in an intercomparison of S2S systems with predicted aerosol.

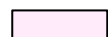
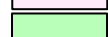


Unlike weather prediction, sub/seasonal results are generally examined in terms of anomaly from some climatology, derived from a series of **hindcasts**.

GMAO's weakly coupled **Ocean Data Assimilation** system runs in near real time and is used to initialize our seasonal forecasts

	Subseasonal	Seasonal
Length of Forecast	45 days	9-12 months
Frequency of forecasts	Every 5 days	Every 5 days
Number of Ensembles	4 per start date	Total of 10 per month
Frequency of submission	Once per week	Once per month
Initial Conditions from	GEOS ODAS	GEOS ODAS
Hindcasts	1999-2016	1980-2016/7

Sub/Seasonal Forecast/Hindcast Schedule



-  - not included in the seasonal forecast, included in SubX
-  - single forecast for seasonal
-  - forecast ensemble of 7 members for seasonal
-  - composite ensemble of 10 members submitted to NMME/seasonal

1st release on Nov 6

2nd release on Dec 6

New Seasonal Prediction System – Sample Results

Experiments:

- Full Seasonal hindcast suite with October/December initial conditions
- Seasonal hindcasts from selected March initial conditions (development phase)
- Near real time Ocean Data Assimilation System
- Free-running (equilibrated) simulation with “perpetual” 2000 conditions

Comparison with old S2S system:

- Clear improvements – Near surface temperature over land/ocean, sea ice fraction, some aspects of ocean circulation
- Status quo – Equatorial Pacific metrics for ENSO, some aspects of precipitation
- Some loss of fidelity – precipitation in equatorial Pacific

2-meter temperature bias - October I.C. Hindcasts

Lead 1 (Nov)

Lead 4 (Feb)

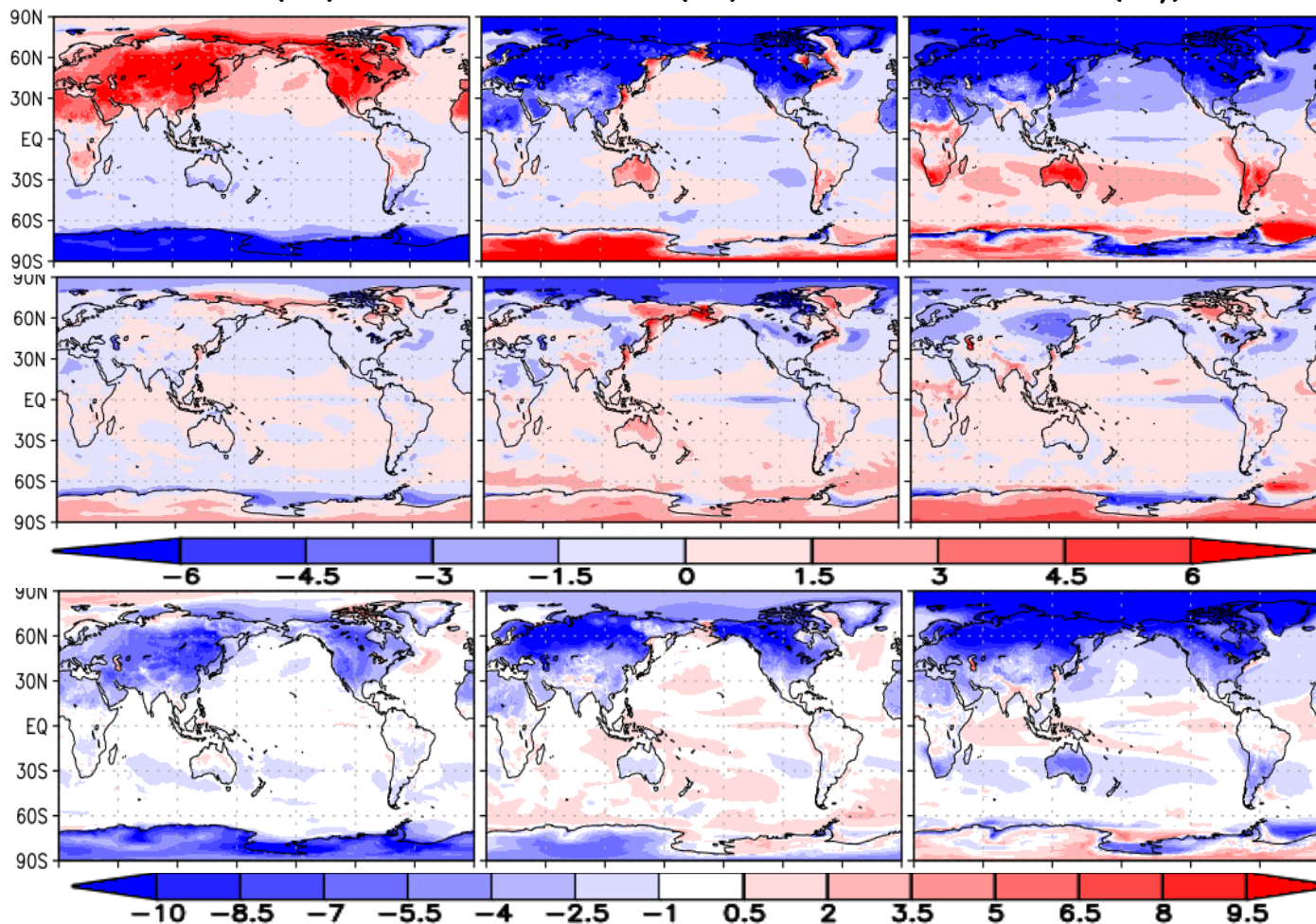
Lead 7 (May)

S2S-1_0
(previous)

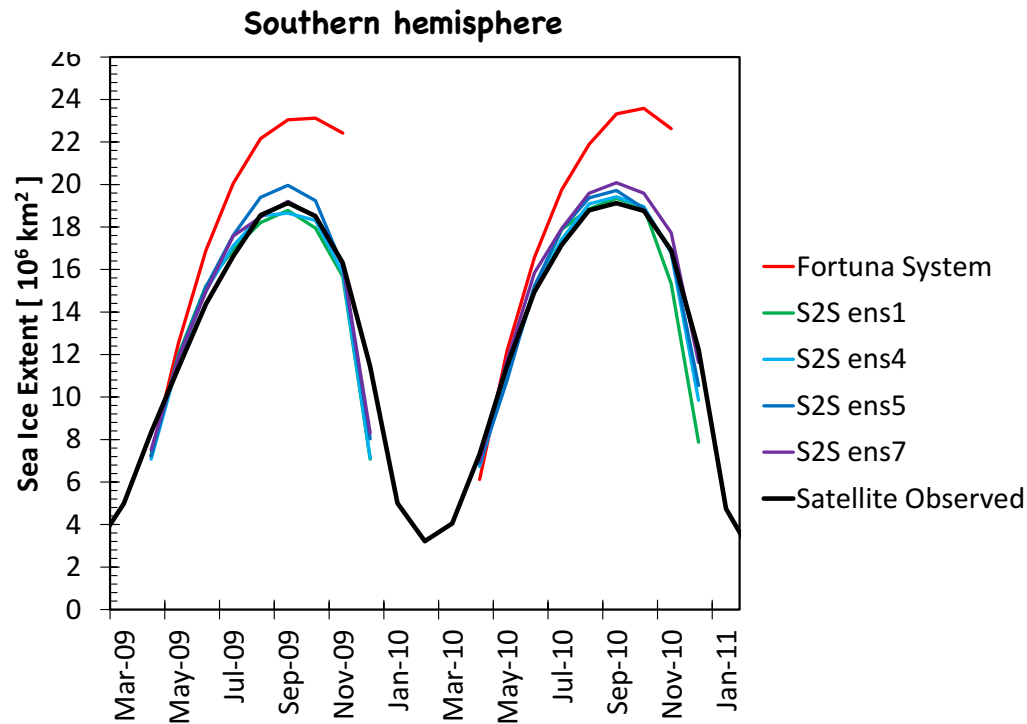
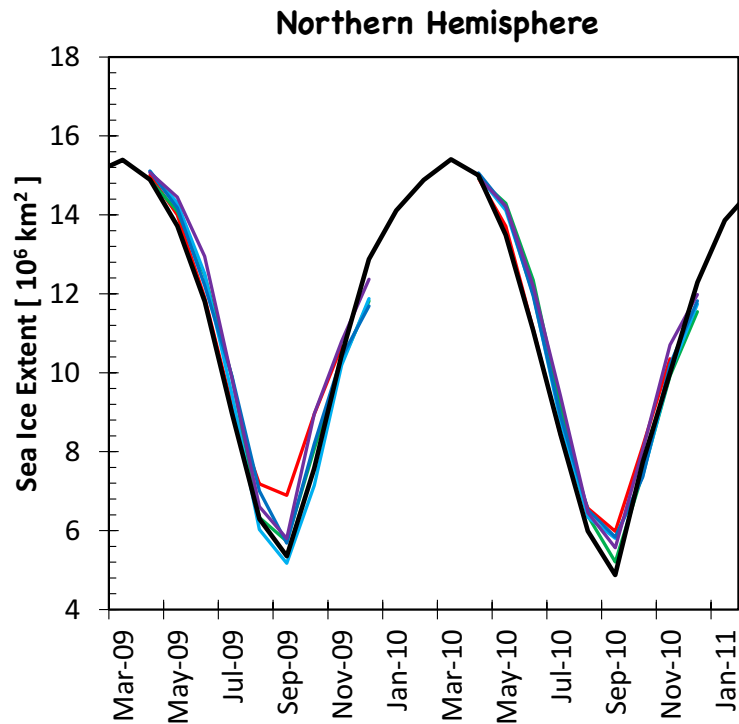
S2S-2_1
(new)

Absolute
Difference

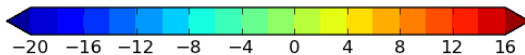
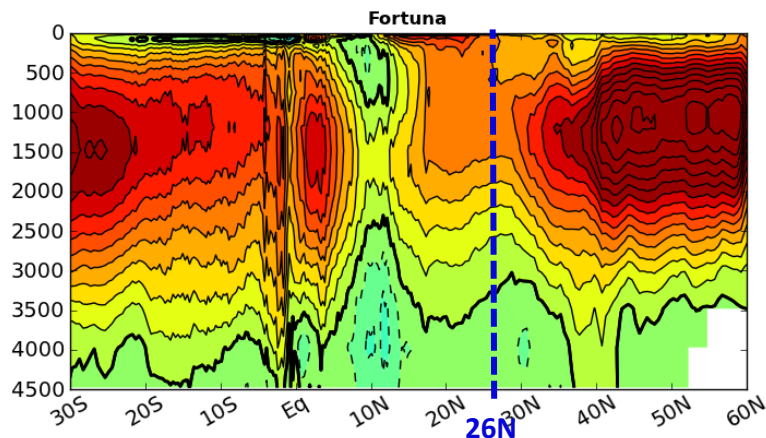
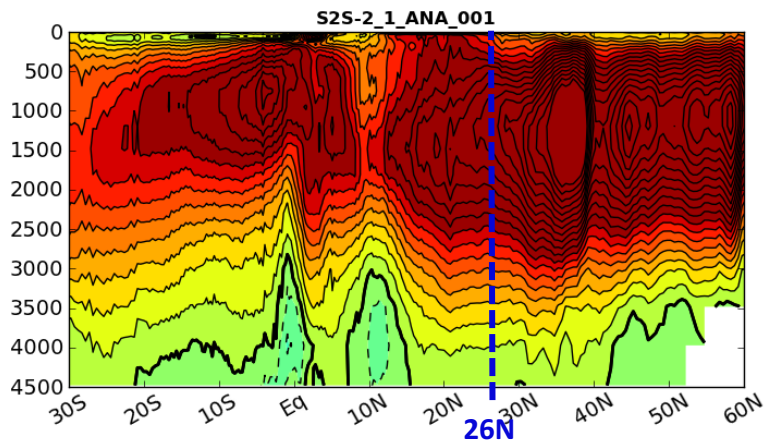
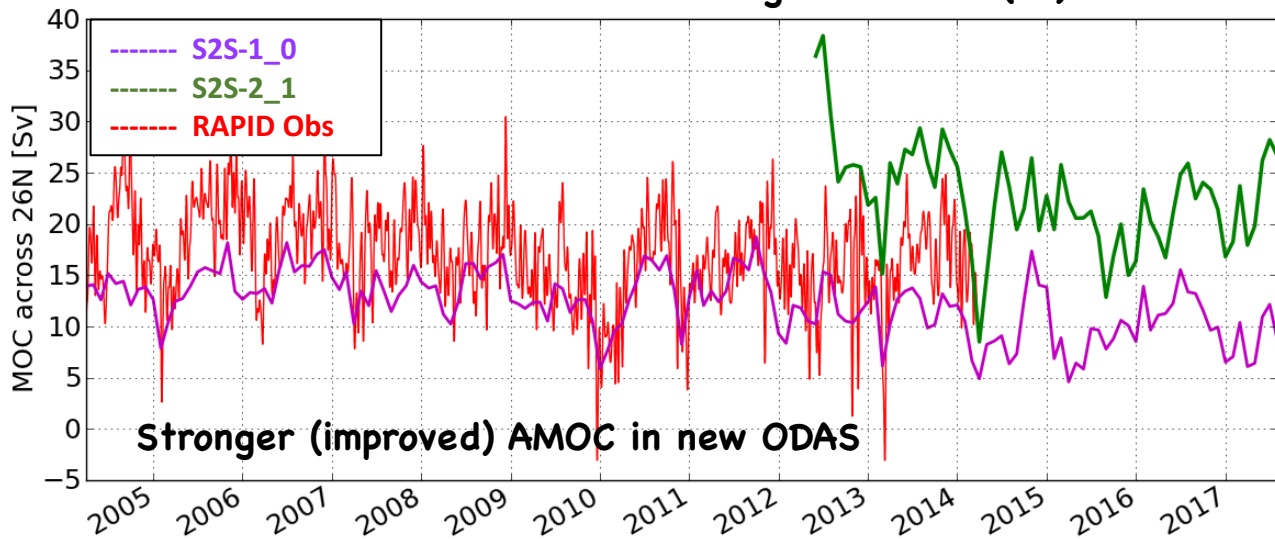
(blue → new
system has
less bias)



Sea Ice Extent Forecasts for 2009 and 2010 Initialized on 02-March

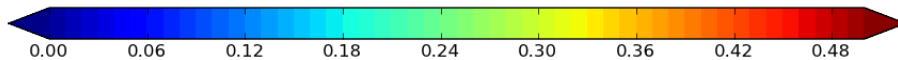
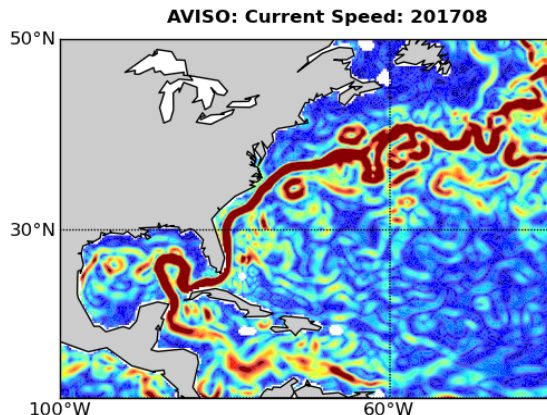
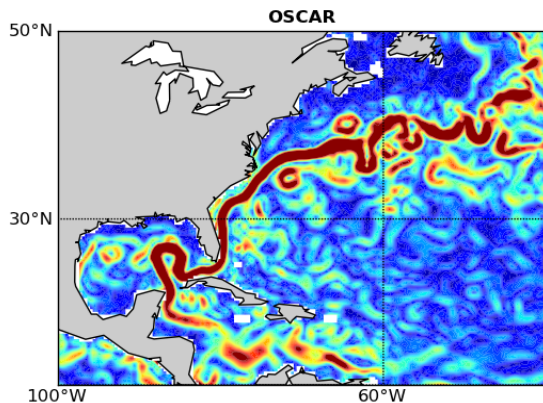
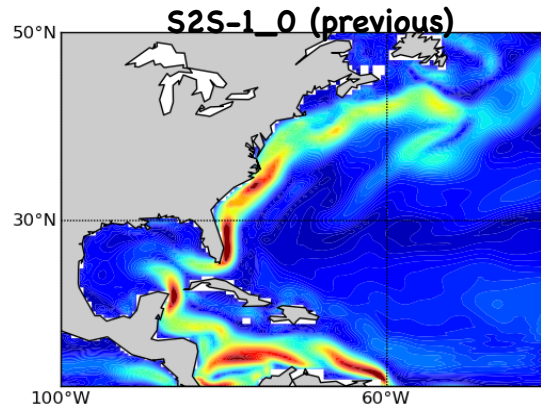
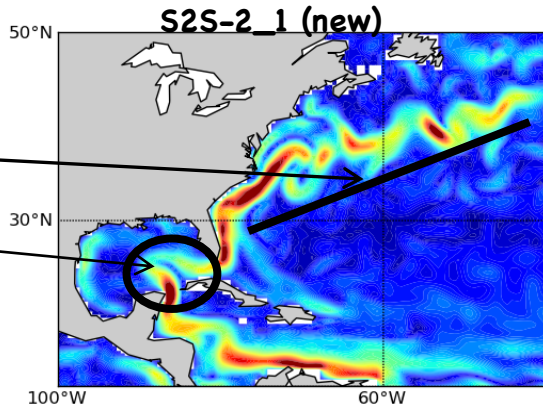


Atlantic Meridional Overturning Circulation (Sv)

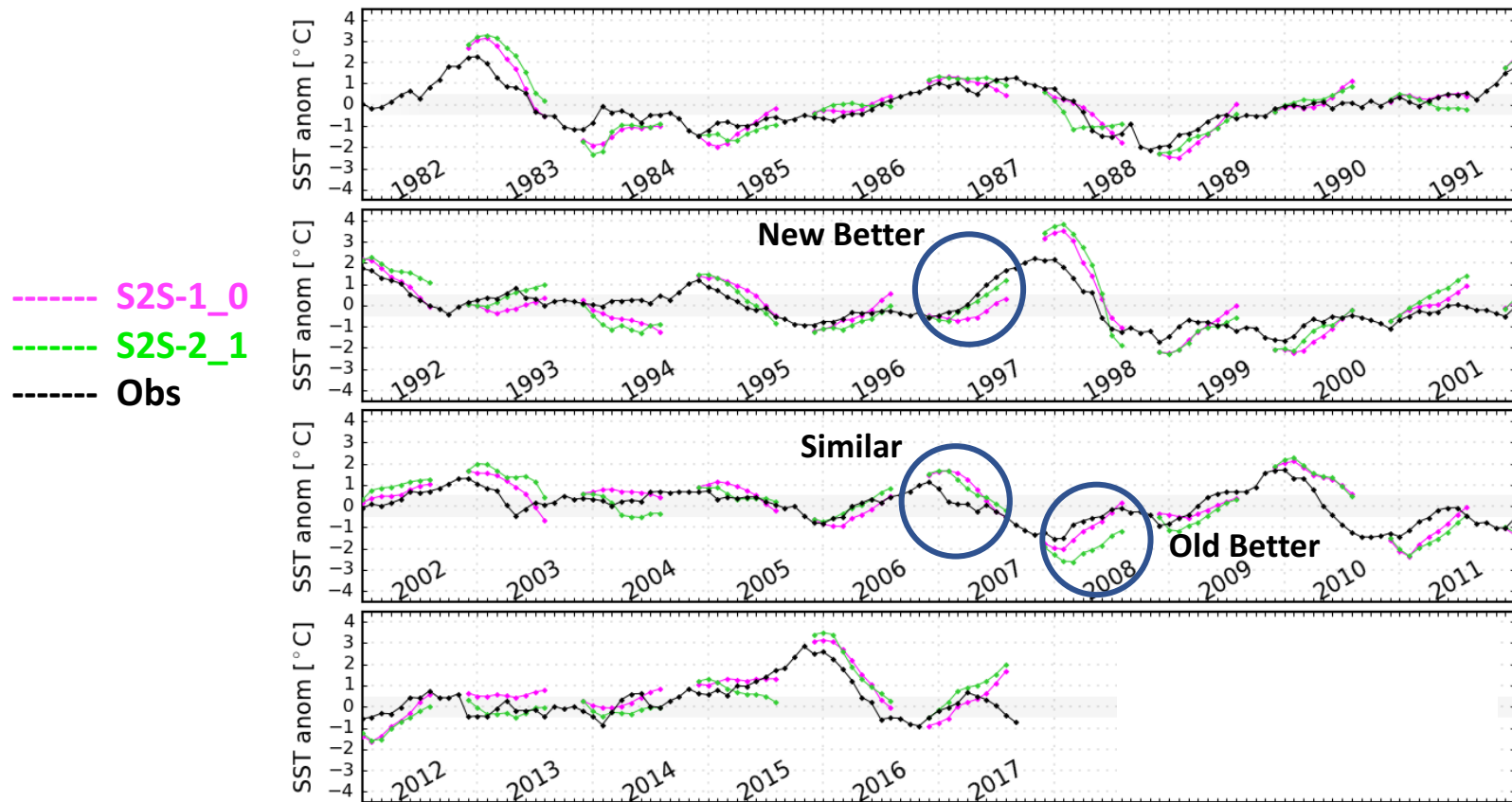


Current Speed in m/sec for August, 2017

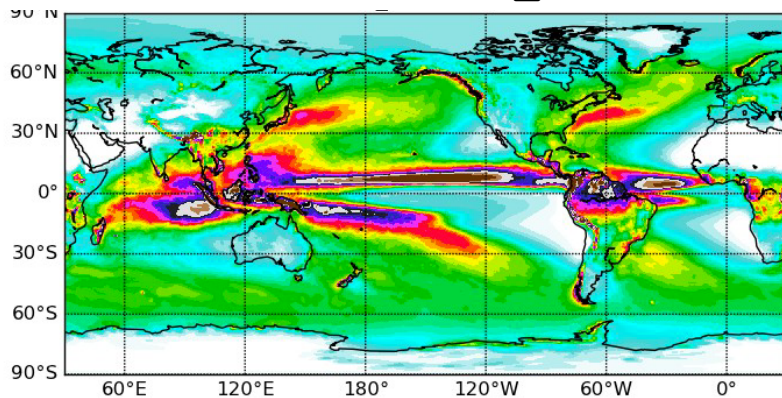
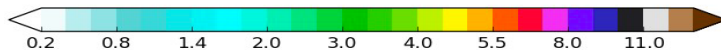
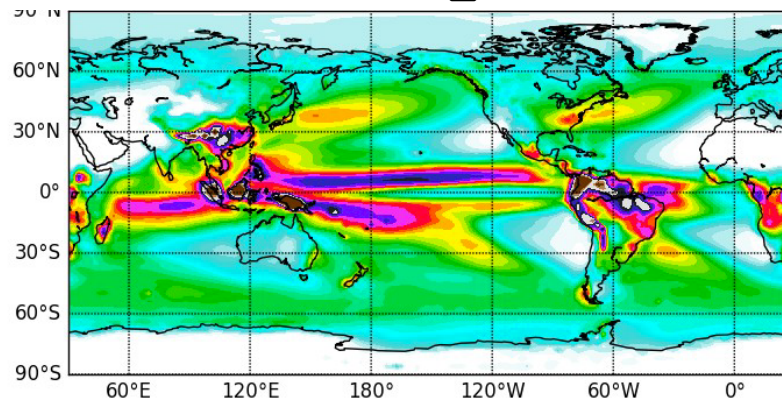
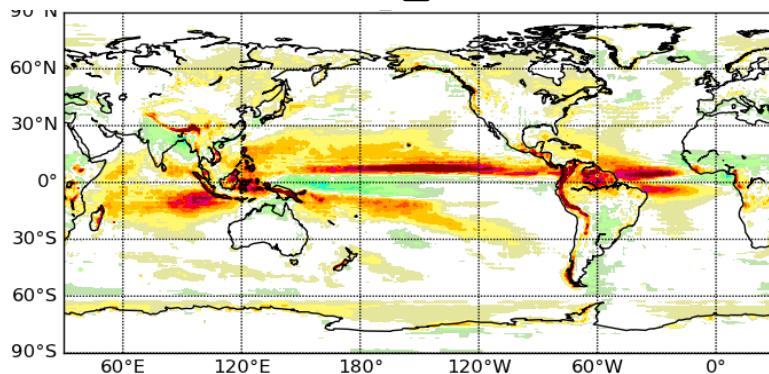
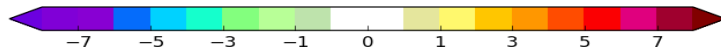
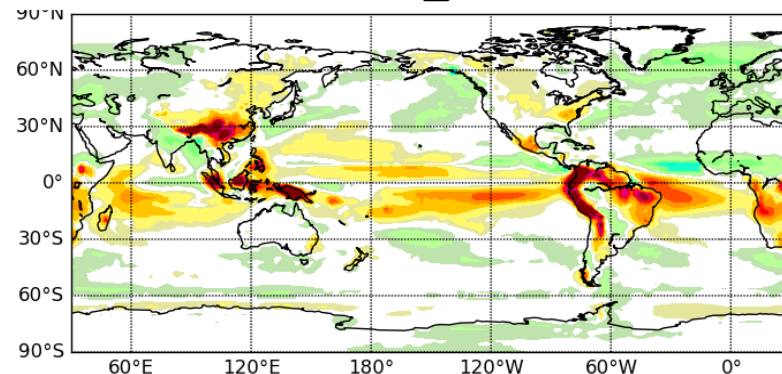
Gulf Stream
and
Loop Current
are better
resolved in new
ODAS



NINO 3.4 Index, December IC Hindcasts



Precipitation Annual Mean

GEOS S2S-2_1**GEOS S2S-1_0****GEOS S2S-2_1 - GPCP****GEOS S2S-1_0 - GPCP**

Summary/Looking Forward

GMAO S2S system being used to demonstrate usefulness of new and existing NASA data types

- New S2S system went “live” for seasonal forecasts in Nov. (subseasonal live since August)
- Along-track altimetry being assimilated
- Clear improvements in new system in surface temperature, sea ice extent and some aspects of ocean circulation
- Some loss of fidelity in some aspects of Pacific tropical precipitation

Next system upgrade due in January, 2019, will include:

- Increase in ocean model resolution to ~ 0.25 deg, 50 levels
- Incorporation of satellite sea surface salinity data in ocean assimilation
- Use of sea ice thickness information from CryoSat-2/ICESat-2 in ocean assimilation
- Production of a 30+ year weakly coupled atmosphere-ocean reanalysis (“MERRA-2 Ocean” reanalysis)

Developments also include:

- Carbon cycle
- Land assimilation of SMAP soil moisture



GMAO Next System Under Development – January 2019

- Resolution: AGCM: c180 (~ 0.5 deg), 72 levels OGCM: MOM5 with ~ 0.25 deg, 50 levels
- AGCM: Two-moment microphysics, interactive aerosols, may also include shallow convection, Grell-Freitas convection, Catchment CN, currently under development/testing in GMAO
- Predictive biomass burning emissions
- Ice Sheet runoff to proper location
- “Snow darkening” parameterization
- New “skin layer” – diurnal warming and cool layer (now only in GMAO NWP system)
- ODAS: LETKF
- Modified methodology for the weakly coupled Data Assimilation System
- Addition of Tskin analysis (now only in GMAO NWP system)
- Inclusion of new data types (extent, thickness) in sea ice assimilation in ODAS
- Initialization – 30+ year LETKF ODAS reanalysis (“MERRA-2 Ocean” reanalysis)
- Alternative ensemble perturbations (current reliability too low)
- Bias corrected forecasts

Previous Seasonal Prediction System - GEOS S2S-1_0

Model

- AGCM: Post-MERRA generation, 1 degree, 72 hybrid sigma-pressure levels;
- OGCM: MOM4p1, 0.5 degree, 40 levels;
- Sea Ice: CICE-4.0

Weakly (Loosely) Coupled Ocean Data Assimilation System

- atmosphere is “replayed” to MERRA, precipitation correction over land;
- EnOI ocean and sea ice analysis – run from 1980 to present (“MERRA-ocean”);
- bred vectors and difference between two analyses is used to produce perturbations to initialize ensemble forecasts

Observations

- SST from CMIP5 prior to 1982 and Reynolds from 1982 to present;
- temperature and salinity profiles from XBTs and CTD sensors, tropical moored buoy array – TAO/TRITON, PIRATA, and RAMA arrays and Argo floats, with profiles from the Argo Global Data Assembly Center (GDAC);
- sea ice concentration from the National Snow and Ice Data Center (NSIDC).

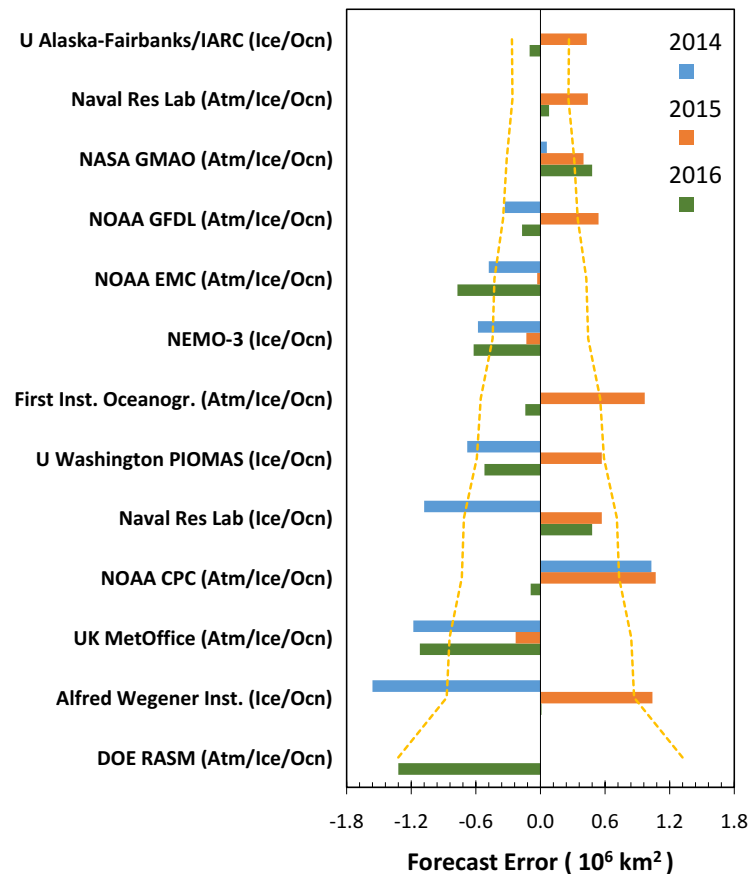
GMAO and the ARCUS Sea Ice Outlook

SIPN/ARCUS June Sea Ice Outlooks of September Mean Extent: 2014-2016

Sea Ice Outlook is an international competition to forecast average September ice extent from 1,2, and 3 months in advance.

The GMAO has performed among the top models over the last few years.

For 2017, the GMAO forecast was within $0.03 \times 10^6 \text{ km}^2$.



Precipitation bias – October I.C. Hindcasts

**Absolute
Difference**

**(blue means
new system
has less bias)**

